Turbine 1 :

```
Patm=101.3; %[kPa]
T1= 288; %inlet temp to compressor [K] [ISO]
DeltaP=1.2;%pressure drop in air filter [kpa]
PR=15;%pressure ratio
T3=1373;%turbine inlet temp. [K]
nC=0.84;%compressor isentropic efficiency
nT=0.89;%Turbine isentropic efficiency
HL=0.05;%percentage of heat loss from combustion chamber
PL=0.05;% pressure drop in Combustion Chamber
LHV=36000;%[kJ/kg]
CombEff=0.94;%Combustion efficiency
Kc=1.4;
KT=1.33;
Cpg=1.2;
P4=105;%Pressure of the gases at turbine exit[kPa]
Cpc=1.007;
Cpt=1.15;
power=140000;%Turbine output Power[KW]
%compressor
T2s=T1*(PR)^((Kc-1)/Kc);
T2=((T2s-T1)/nC)+T1;
P1=Patm-DeltaP;
P2=P1*PR;
%combustion chamber
qin=Cpg*(T3-T2); %[kJ/kg]
mf=qin/(LHV* CombEff *(1-HL)); %kg of fuel/1kg gases
%Expansion Ratio
P3=P2*(1-PL);
ER=P3/P4;
%Turbine
T4s=T3*(1/ER)^((KT-1)/KT);
T4=T3-nT*(T3-T4s);
%performance
Wc=Cpc*(T2-T1);
Wt=Cpt*(T3-T4);
Wnet=Wt-Wc;
nCycle=(Wnet/qin)*100. ;
BWR=(Wc/Wt)*100;
Diff_PR_ER =PR-ER;% Difference between pressure ratio and expansion ratio
%masses
```

```
mgdot=power/Wnet; %kg/sec
mgdot_hour=mgdot*3600; %kg/h
mfdot=mf*mgdot; %kgfuel/s
madot=mgdot-mfdot; % total air kg/s
mair_per_1kgfuel=madot/mfdot;
mfg=mfdot/mgdot; % Ratio of kg of fuel per kg of gas
%heat rate
HR=mfdot*3600*CombEff*LHV/(power);
%powers
Power_c=Cpc*madot*(T2-T1);
Pc_PG=Power_c/power;
%combustion
%Excess_air=0.6; %(5)
f_air_ratio_a=0.046; %(6)
%phi=; %(7)
%act_fuel_air_by_vol=;(8)
R1=0.60;n1=1;m1=4; % for reminder, if not exist put them zero
R2=0.2;n2=3;m2=8;
R3=0.2;n3=2;m3=6;
R4=0;n4=0;m4=0;
patm=101.3 ;
O=16;N=14;C=12;H=1;Air=28.84; %molar mass
Y=R1*n1+R2*n2+R3*n3+R4*n4;% coefficient of carbon dioxide y CO2 [moles]
Z=(R1*m1+R2*m2+R3*m3+R4*m4)./2;% coefficient of water z H2o [moles]
X=(2*Y+Z)./2; %cofficient of nitrogen 3.76 x N2 [moles]
fuel_molar_mass=R1.*(C*n1+H*m1)+R2.*(C*n2+H*m2)+R3.*(C*n3+H*m3)+R4.*(C*n4+H*m4);
f_air_ratio_th=fuel_molar_mass/(X*(1+3.76)*Air);
%phi=act_fuel_air_by_vol./((1/(X*(1+3.76)))); (8)
%phi=1/(Excess_air+1);% equivalance Ratio (5)
%f_air_ratio_a=phi*f_air_ratio_th ; %(5)(7)(8)
phi=f_air_ratio_a./f_air_ratio_th; %(6)
Excess_air=((1)./phi-1); %(6)(7)(8)
N_H2O=Z;
Np=Y+Z+( Excess_air )*X+(1+ Excess_air)*3.76*X;
%%%percentage co2
per_co2=(Y./Np)*100;
%%% content of carbon dioxide in the product [g/kwh]
CO2_kg_kwh= ((Y*44)/(fuel_molar_mass)*mfdot*3600)/power; %[kg/kwh]
CO2_g_kwh= CO2_kg_kwh*1000.; %[g/kwh]
%%%percentage H2O
per_H2O=(Z./Np)*100;
%percentage O2
per_O2=(((Excess_air )*X)./Np)*100;
%percentage N2
per_N2=(((1+ Excess_air)*3.76*X)/Np)*100;
```

```
%Dew point temperature
P_H2O=(N_H2O./Np)*patm;% partial pressure of h2O
Tdew= XSteam('Tsat_p',P_H2O/100); %[C]
Tdew1= (XSteam('Tsat_p',P_H2O/100)); %[C] %Product dew point temperature
if(phi>1)
'Rich Mixture'
elseif(phi<1)
'Lean Mixture'
else
'Correct Chemical Mixture'
end
%acutal ratio by volume
act_fuel_air_by_vol=(1/(X*(1+3.76)))*phi;% fuel to air by volume
act_air_fuel_by_vol=1/act_fuel_air_by_vol;% air to fuel by volume
%extra fuel due to heat losses
%qin_kJ_Sec = (mfdot)*LHV*nC*(1-HL); % Hheat addition in combustion in (kJ/s)
%extra_fuel = (qin_kJ_Sec*HL)/LHV; % Fuel rate which been wasted as heat loss (kg fuel/s)
%extra_fuel_Percent = (extra_fuel/mfdot)*100; % Fuel rate which been wasted as heat loss
%Turbine Drop Power Due to Pressure drop in combustion
%T3x = T3;
%P3x = P2;
%P4 = P4;
%ER = P3x/P4; % Expansion Ratio in Turbine
%T4s=T3*(1/ER)^((KT-1)/KT);
%T4=T3-nT*(T3-T4s);
%wtx = Cpt*(T3-T4); % Output work of the turbine (kJ/kg gas) without PL
%wt_drop =((wtx-Wt)/wtx)*100; % Turbine Power drop due to Pressure loss
%combustion chamber no heat loss
qin=Cpg*(T3-T2); %[kJ/kg]
mfnl=qin/(LHV* CombEff); %kg of fuel/1kg gases
%fuel loss due to heat loss in combustion chamber
Percentage_fuel_lost=(( mf- mfnl)/ mf)*100.; %drop in fuel consumption due heat loss in combustion chamber
```

Turbine 2 :

```
Patm=101.3; %[kPa]
T1= 288; %inlet temp to compressor [K] [ISO]
DeltaP=1.7;%pressure drop in air filter [kpa]
PR=11;%pressure ratio
T3=1573;%turbine inlet temp. [K]
nC=0.87;%compressor isentropic efficiency
nT=0.9;%Turbine isentropic efficiency
HL=0.04;%percentage of heat loss from combustion chamber
PL=0.04;% pressure drop in Combustion Chamber
LHV=40000;%[kJ/kg]
CombEff=0.96;%Combustion efficiency
Kc=1.4;
KT=1.33;
Cpg=1.2;
P4=106;%Pressure of the gases at turbine exit[kPa]
Cpc=1.007;
Cpt=1.15;
power=140000;%Turbine output Power[KW]
%compressor
T2s=T1*(PR)^((Kc-1)/Kc);
T2=((T2s-T1)/nC)+T1;
P1=Patm-DeltaP;
P2=P1*PR;
%combustion chamber
qin=Cpg*(T3-T2); %[kJ/kg]
mf=qin/(LHV* CombEff *(1-HL)); %kg of fuel/1kg gases
%Expansion Ratio
P3=P2*(1-PL);
ER=P3/P4;
%Turbine
T4s=T3*(1/ER)^((KT-1)/KT);
T4=T3-nT*(T3-T4s);
%performance
Wc=Cpc*(T2-T1);
Wt=Cpt*(T3-T4);
Wnet=Wt-Wc;
nCycle=(Wnet/qin)*100. ;
BWR=(Wc/Wt)*100;
Diff_PR_ER =PR-ER;% Difference between pressure ratio and expansion
ratio
%masses
mgdot=power/Wnet; %kg/sec
```

```
mgdot_hour=mgdot*3600; %kg/h
mfdot=mf*mgdot; %kgfuel/s
madot=mgdot-mfdot; % total air kg/s
mair_per_1kgfuel=madot/mfdot;
mfg=mfdot/mgdot; % Ratio of kg of fuel per kg of gas
%heat rate
HR=mfdot*3600*CombEff*LHV/(power);
%powers
Power_c=Cpc*madot*(T2-T1);
Pc_PG=Power_c/power;
%combustion
%Excess_air=0.6; %(5)
f_air_ratio_a=0.049; %(6)
%phi=; %(7)
%act_fuel_air_by_vol=;(8)
R1=0.80;n1=1;m1=4; % for reminder, if not exist put them zero
R2=0.1;n2=2;m2=6;
R3=0.1;n3=2;m3=4;
R4=0;n4=0;m4=0;
patm=101.3 ;
O=16;N=14;C=12;H=1;Air=28.84; %molar mass
Y=R1*n1+R2*n2+R3*n3+R4*n4;% coefficient of carbon dioxide y CO2
[moles]
Z=(R1*m1+R2*m2+R3*m3+R4*m4)./2;% coefficient of water z H2o [moles]
X=(2*Y+Z)./2; %cofficient of nitrogen 3.76 x N2 [moles]
fuel_molar_mass=R1.*(C*n1+H*m1)+R2.*(C*n2+H*m2)+R3.*(C*n3+H*m3)
+R4.*(C*n4+H*m4);
f_air_ratio_th=fuel_molar_mass/(X*(1+3.76)*Air);
%phi=act_fuel_air_by_vol./((1/(X*(1+3.76)))); (8)
%phi=1/(Excess_air+1);% equivalance Ratio (5)
%f_air_ratio_a=phi*f_air_ratio_th ; %(5)(7)(8)
phi=f_air_ratio_a./f_air_ratio_th; %(6)
Excess_air=((1)./phi-1); %(6)(7)(8)
N_H2O=Z;
Np=Y+Z+( Excess_air )*X+(1+ Excess_air)*3.76*X;
%%%percentage co2
per_co2=(Y./Np)*100;
%%% content of carbon dioxide in the product [g/kwh]
CO2_kg_kwh= ((Y*44)/(fuel_molar_mass)*mfdot*3600)/power; %[kg/kwh]
CO2_g_kwh= CO2_kg_kwh*1000.; %[g/kwh]
%%%percentage H2O
per_H2O=(Z./Np)*100;
%percentage O2
per_O2=(((Excess_air )*X)./Np)*100;
%percentage N2
per_N2=(((1+ Excess_air)*3.76*X)/Np)*100;
```

```
%Dew point temperature
P_H2O=(N_H2O./Np)*patm;% partial pressure of h2O
Tdew= XSteam('Tsat_p',P_H2O/100); %[C]
Tdew1= (XSteam('Tsat_p',P_H2O/100)); %[C] %Product dew point
temperature
if(phi>1)
'Rich Mixture'
elseif(phi<1)
'Lean Mixture'
else
'Correct Chemical Mixture'
end
%acutal ratio by volume
act_fuel_air_by_vol=(1/(X*(1+3.76)))*phi;% fuel to air by volume
act_air_fuel_by_vol=1/act_fuel_air_by_vol;% air to fuel by volume
%extra fuel due to heat losses
%qin_kJ_Sec = (mfdot)*LHV*nC*(1-HL); % Hheat addition in combustion in
(kJ/s)
%extra_fuel = (qin_kJ_Sec*HL)/LHV; % Fuel rate which been wasted as heat
loss (kg fuel/s)
%extra_fuel_Percent = (extra_fuel/mfdot)*100; % Fuel rate which been
wasted as heat loss
%Turbine Drop Power Due to Pressure drop in combustion
%T3x = T3;
%P3x = P2;
%P4 = P4;
%ER = P3x/P4; % Expansion Ratio in Turbine
%T4s=T3*(1/ER)^((KT-1)/KT);
%T4=T3-nT*(T3-T4s);
%wtx = Cpt*(T3-T4); % Output work of the turbine (kJ/kg gas) without PL
%wt_drop =((wtx-Wt)/wtx)*100; % Turbine Power drop due to Pressure loss
%combustion chamber no heat loss
qin=Cpg*(T3-T2); %[kJ/kg]
mfnl=qin/(LHV* CombEff); %kg of fuel/1kg gases
%fuel loss due to heat loss in combustion chamber
Percentage_fuel_lost=(( mf- mfnl)/ mf)*100.; %drop in fuel consumption due
heat loss in combustion chamber
```

Turbine 3 :

```
Patm=101.3; %[kPa]
T1= 288; %inlet temp to compressor [K] [ISO]
DeltaP=1.7;%pressure drop in air filter [kpa]
PR=15;%pressure ratio
T3=1573;%turbine inlet temp. [K]
nC=0.87;%compressor isentropic efficiency
nT=0.9;%Turbine isentropic efficiency
HL=0.04;%percentage of heat loss from combustion chamber
PL=0.04;% pressure drop in Combustion Chamber
LHV=40000;%[kJ/kg]
CombEff=0.96;%Combustion efficiency
Kc=1.4;
KT=1.33;
Cpg=1.2;
P4=106;%Pressure of the gases at turbine exit[kPa]
Cpc=1.007;
Cpt=1.15;
power=140000;%Turbine output Power[KW]
%compressor
T2s=T1*(PR)^((Kc-1)/Kc);
T2=((T2s-T1)/nC)+T1;
P1=Patm-DeltaP;
P2=P1*PR;
%combustion chamber
qin=Cpg*(T3-T2); %[kJ/kg]
mf=qin/(LHV* CombEff *(1-HL)); %kg of fuel/1kg gases
%Expansion Ratio
P3=P2*(1-PL);
ER=P3/P4;
%Turbine
T4s=T3*(1/ER)^((KT-1)/KT);
T4=T3-nT*(T3-T4s);
%performance
Wc=Cpc*(T2-T1);
Wt=Cpt*(T3-T4);
Wnet=Wt-Wc;
nCycle=(Wnet/qin)*100. ;
BWR=(Wc/Wt)*100;
Diff_PR_ER =PR-ER;% Difference between pressure ratio and expansion
ratio
%masses
mgdot=power/Wnet; %kg/sec
mgdot_hour=mgdot*3600; %kg/h
mfdot=mf*mgdot; %kgfuel/s
madot=mgdot-mfdot; % total air kg/s
mair_per_1kgfuel=madot/mfdot;
mfg=mfdot/mgdot; % Ratio of kg of fuel per kg of gas
```

```
%heat rate
HR=mfdot*3600*CombEff*LHV/(power);
%powers
Power_c=Cpc*madot*(T2-T1);
Pc_PG=Power_c/power;
%combustion
%Excess_air=0.6; %(5)
f_air_ratio_a=0.049; %(6)
%phi=; %(7)
%act_fuel_air_by_vol=;(8)
R1=0.80;n1=1;m1=4; % for reminder, if not exist put them zero
R2=0.1;n2=2;m2=6;
R3=0.1;n3=2;m3=4;
R4=0;n4=0;m4=0;
patm=101.3 ;
O=16;N=14;C=12;H=1;Air=28.84; %molar mass
Y=R1*n1+R2*n2+R3*n3+R4*n4;% coefficient of carbon dioxide y CO2 [moles]
Z=(R1*m1+R2*m2+R3*m3+R4*m4)./2;% coefficient of water z H2o [moles]
X=(2*Y+Z)./2; %cofficient of nitrogen 3.76 x N2 [moles]
fuel_molar_mass=R1.*(C*n1+H*m1)+R2.*(C*n2+H*m2)+R3.*(C*n3+H*m3)+R4.*(C*
n4+H*m4);
f_air_ratio_th=fuel_molar_mass/(X*(1+3.76)*Air);
%phi=act_fuel_air_by_vol./((1/(X*(1+3.76)))); (8)
%phi=1/(Excess_air+1);% equivalance Ratio (5)
%f_air_ratio_a=phi*f_air_ratio_th ; %(5)(7)(8)
phi=f_air_ratio_a./f_air_ratio_th; %(6)
Excess_air=((1)./phi-1); %(6)(7)(8)
N_H2O=Z;
Np=Y+Z+( Excess_air )*X+(1+ Excess_air)*3.76*X;
%%%percentage co2
per_co2=(Y./Np)*100;
%%% content of carbon dioxide in the product [g/kwh]
CO2_kg_kwh= ((Y*44)/(fuel_molar_mass)*mfdot*3600)/power; %[kg/kwh]
CO2_g_kwh= CO2_kg_kwh*1000.; %[g/kwh]
%%%percentage H2O
per_H2O=(Z./Np)*100;
%percentage O2
per_O2=(((Excess_air )*X)./Np)*100;
%percentage N2
per_N2=(((1+ Excess_air)*3.76*X)/Np)*100;
%Dew point temperature
P_H2O=(N_H2O./Np)*patm;% partial pressure of h2O
Tdew= XSteam('Tsat_p',P_H2O/100); %[C]
Tdew1= (XSteam('Tsat_p',P_H2O/100)); %[C] %Product dew point
temperature
if(phi>1)
'Rich Mixture'
elseif(phi<1)
'Lean Mixture'
else
'Correct Chemical Mixture'
end
%acutal ratio by volume
act_fuel_air_by_vol=(1/(X*(1+3.76)))*phi;% fuel to air by volume
act_air_fuel_by_vol=1/act_fuel_air_by_vol;% air to fuel by volume
```

```
%extra fuel due to heat losses
%qin_kJ_Sec = (mfdot)*LHV*nC*(1-HL); % Hheat addition in combustion in
(kJ/s)
%extra_fuel = (qin_kJ_Sec*HL)/LHV; % Fuel rate which been wasted as
heat loss (kg fuel/s)
%extra_fuel_Percent = (extra_fuel/mfdot)*100; % Fuel rate which been
wasted as heat loss
%Turbine Drop Power Due to Pressure drop in combustion
%T3x = T3;
%P3x = P2;
%P4 = P4;
%ER = P3x/P4; % Expansion Ratio in Turbine
%T4s=T3*(1/ER)^((KT-1)/KT);
%T4=T3-nT*(T3-T4s);
%wtx = Cpt*(T3-T4); % Output work of the turbine (kJ/kg gas) without PL
%wt_drop =((wtx-Wt)/wtx)*100; % Turbine Power drop due to Pressure loss
%combustion chamber no heat loss
qin=Cpg*(T3-T2); %[kJ/kg]
mfnl=qin/(LHV* CombEff); %kg of fuel/1kg gases
%fuel loss due to heat loss in combustion chamber
Percentage_fuel_lost=(( mf- mfnl)/ mf)*100.; %drop in fuel consumption
due heat loss in combustion chamber
```

T	**Gas Turbine No. 1**	**Gas Turbine No. 2**	**Gas Turbine No. 3**
1	**288**	**288**	**288**
2	**688**	**613.74**	**674.59**
3	**1373**	**1573**	**1573**
4	**790.655**	**958.406**	**899.07**

(a) Compare your answers with those given

Parameters	**Turbine 1**	**Turbine 2**	**Turbine 3**
Excess Air Ratio	**33.24%**	**22.9%**	**22.9%**
P_C/P_G	**1.47**	**0.84**	**0.98**
Exhaust gases temperature K	**790.66**	**958.406**	**899.07**
CO_2 (g/kWh)	**996**	**842.5**	**774.82**
Work Net (kJ/kg)	**266.494**	**378.77**	**385.72**
Thermal Efficiency	**32%**	**33%**	**35.78%**
Heat Rate (Power = 140 MW)	**11682**	**11397**	**10481**
Dew Point Temperature	**52**	**54**	**54**
% Of Fuel Lost due to Heat Loss in the Combustion Chamber	**5%**	**4%**	**4%**

(b) Indicate which turbine has better performance &why?

Turbine 3 better performance: -

1- Higher efficiency

2- Lower heat rate
3- Higher work net
4- Lower grams of CO2 produced